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Technological Progress in Reducing CFC (Chlorofluorocarbon) and Halon Emissions

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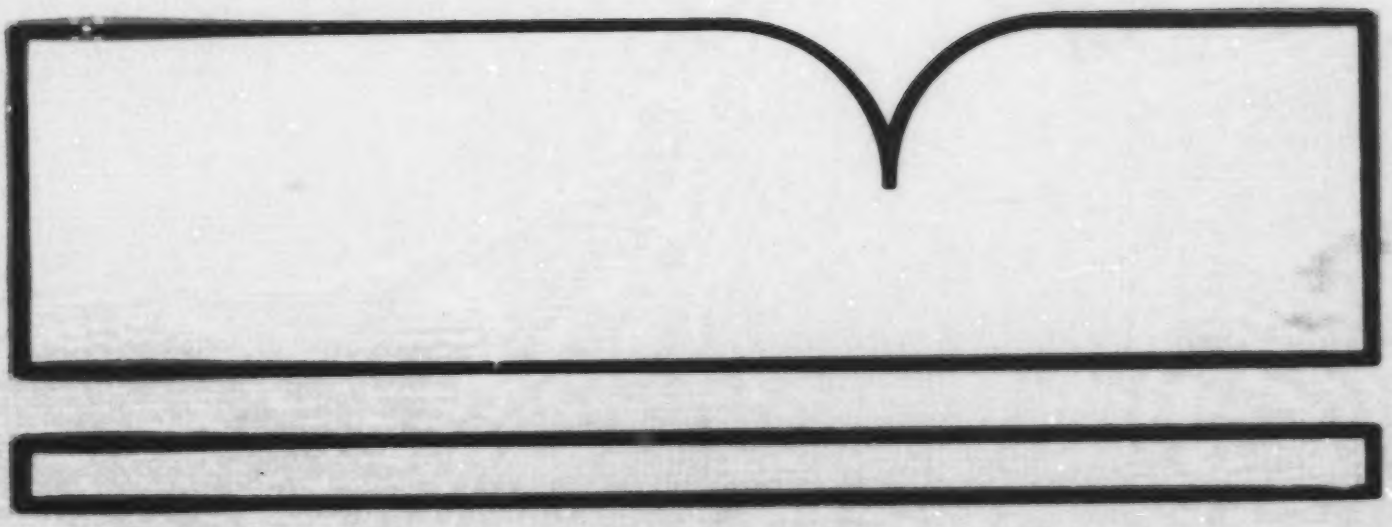

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TECHNOLOGICAL PROGRESS IN REDUCING CFC AND HALON EMISSIONS

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16. ABSTRACT The paper discusses EPA's development of a technological program to implement (in the U.S.) the Montreal Protocol on Substances that Deplete the Ozone Layer. EPA's Office of Air and Radiation (OAR) has the lead for developing the technical and economic goals of the program, and EPA's Office of Research and Development (ORD) has the lead in providing technical support to meet the goals, including both short-term projects and long-term research. EPA's strategy is to target the halon and high chlorofluorocarbon (CFC)-using industries or industry subgroups to identify opportunities to reduce CFC and halon usage and find alternatives. When such opportunities are found, cooperative industry/government groups are formed to identify and solve the problems that impede transition away from CFC and halon usage. Other groups (including academic, non-profit research institutes, other government agencies, and foreign individuals or groups) are invited to join in the effort if they have a special expertise or interest. Identifying the high-use industry sectors and subsectors is not difficult; however, identifying appropriate industries, individuals, and groups who are willing to (and can) influence industry usage of CFCs is not easy.

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The Environmental Protection Agency (EPA) is developing a technological program to implement the Montreal Protocol On Substances That Deplete The Ozone Layer in the United States.(1) The EPA's Office of Air and Radiation (OAR) has the lead for developing the technical and economic goals of the program. The Office of Research and Development (ORD) has the lead in providing technical support to meet these goals. This includes both carrying out short-term projects and conducting long-term research.

The EPA strategy is to target the halon and high chlorofluorocarbon (CFC)-using industries or industry subgroups to determine if there are opportunities to reduce CFC and halon usage and find alternatives. When such opportunities are found, cooperative industry/government groups are formed to identify and solve the problems that impede transition away from CFC and halon usage. Other groups (including academic, non-profit research institutes, other government agencies, and foreign individuals or groups) are invited to join in the effort if they have a special expertise or interest.

Identifying the high-use industry sectors and subsectors is not difficult. That information was gathered by OAR and ORD and published in the Regulatory Impact Analysis (RIA) for the domestic rule that was published in final form on August 12, 1988.(2) Seventy-two industrial usage categories were identified. The largest were refrigeration, insulation foam, food packaging, electronics cleaning, and automobile air conditioners. Halons are used primarily for fire extinguishment.

Identifying appropriate industries, individuals, and groups who are willing to and can influence industry usage of CFCs is not easy. This has been OAR's role. It has taken less than a year of discussions to develop trust, some commitment to act cooperatively, and the outlines of an approach to solving the problem. It can take longer than that to do the research. EPA uses its authority under the domestic regulation and an Advance Notice of Proposed Rule-Making (ANPRM) to encourage cooperation.(3) The ANPRM says that EPA could restrict certain uses of CFCs and halons and does not view favorably a switch to use of other ozone-depleting compounds.

EPA has chosen, however, to try voluntary cooperative efforts as a faster, more flexible, and possibly surer route to change. Normally, EPA may spend $1 million for the analysis and research to promulgate a regulation. After promulgation, there are usually law suits by industry and environmental groups that can delay implementation for several years. A voluntary cooperative agreement, in contrast, can require only $100,000 in EPA engineering research funds. It is likely to be implemented soon and not contested by the parties (including environmental groups) that have been involved in its development.

Once key individuals and groups are identified, a meeting is held to start identifying problems, possible solutions, timetables, and responsibilities. OAR organizes and staffs or uses ORD to staff these meetings. An important part of industry involvement is that it contributes resources to help meet the rapid timetable that is set. After a group is formed, action usually occurs over at least 1 to 2 years. In some areas, such as refrigeration, foams, and halon substitutes, there is a need to fill a gap in basic research and continued improvements are needed. This will require continuing Agency involvement. ORD research will provide the basis for technical support over a number of years to achieve the necessary improvements. Involvement in this research permits ORD staff to keep abreast of the basic science and technology in the field and advise OAR on the technical merits of industry activities and proposals.

As the CFC and halon reductions become more stringent under the Montreal Protocol and as the problems of the larger user industries are solved, smaller industrial user categories will be addressed. One of the barriers to finding alternatives for the smaller user groups is that the producers do not find it economically attractive to develop new products for limited markets. EPA can assist, however, in helping identify needs and by encouraging companies to cooperate and share findings about alternatives and research results.

International Competition

Because of the global nature of stratospheric ozone depletion, the U.S. acting alone cannot solve the problem. U.S. leadership, however, involves finding ways to encourage other countries to join the Protocol. According to current estimates, some developed and developing countries will increase their use of CFCs and halons in the future. Demonstrating to these countries that there are alternatives--especially if they have benefits (such as increased energy efficiency for refrigerators)--will encourage them to join the Protocol and reduce their projected CFC and halon usage.

U.S. chemical and equipment manufacturers have an economic incentive to develop alternatives. The companies that do this first will have a competitive edge in marketing their products both domestically and to other developed and developing countries. Users, too, have an opportunity for a

competitive advantage in changing over early both in absorbing their costs over a longer period and in introducing the changes in their non-U.S. manufacturing operations. Some European countries are already requiring more stringent controls beyond the Protocol limitations so that the more extensive solutions may be developed by U.S. manufacturers to meet European limitations and adopted for domestic U.S. production.

Industry Interest

The industrial members of the ad hoc work groups usually come from several sectors. One of the principal ones includes manufacturers of CFCs and halons. These are generally large corporations; e.g., DuPont, ICI, Allied-Signal, and Great Lakes Chemical. They participate because their market for CFCs and halons is affected by the phasing down, they can learn about the needs of the users to better design alternatives to meet the new market needs, and to act in good faith; e.g., major producers have announced that they will cease production of CFCs by the turn of the century if alternatives are available. DuPont has said that it will cease production of halons then whether or not alternatives exist.(4)

The user industry is involved because users have a need for which alternatives will have to be found. This includes: the auto industry; the electronics, refrigeration, and flexible and rigid foam industries; the firefighting industry and other halon users (including the military); and the aircraft and other industries that require metal cleaning.

The equipment supply industry is involved because substitutes for CFCs and halons may not be drop-in substitutes and could, therefore, require engineering changes and redesign, and alternatives could involve totally different equipment needs and uses. For example, the electronics industry could change to no-flux or non-solder attachment.

The contributions by industry to the cooperative efforts must be substantial in order to be meaningful. They can include use of specialized research and production facilities and equipment, expert personnel, donation of equipment for testing, participation in cooperative research projects, and contribution of funds for such cooperative research.

Cooperative Research

For the ad hoc working groups to be most effective, they must share information especially related to new practices and new findings that will benefit U.S. industry. One of the keys to this, beyond the creation of the working groups or consortia themselves, is use of the Cooperative Research Act.(5) EPA has worked with the Department of Justice to take advantage of the provisions of the Act that permit companies to cooperate in research for environmental protection without concern that they will be accused of anti-trust violations. EPA has used these provisions for developing cooperative

research with the automobile manufacturing industry and is looking into its use for the electronics and firefighting industries. AT&T and Intel are two of the electronics companies that have expressed the view that their industry would be better served if information were shared rather than held proprietary.(6)

There are many advantages of information sharing on research. For example, if each of five companies spent $1 million on research by working cooperatively, they could be sure that they did not duplicate research and the $5 million was most effectively spent. Sharing both positive and negative results can be useful. For example, knowing that one company found toxicological problems with a certain substance could save another company much cost and time in not fruitlessly trying to develop that compound. Both small and large companies can participate. For example, a database on alternatives to which all participating companies contribute can help to produce completeness in what is known and to enable companies, large or small, that are pursuing one line of research to benefit from the work of companies that may take an entirely different approach.

A fully functioning consortium can have any interested party, whether member or not, bring a possible research project to it for consideration. The consortium can put common funding into it, one or more of the members can decide to fund it, it can be referred to a Federal agency for possible funding, or the consortium can simply endorse it or state that the results are not likely to be fruitful in light of the consortium's overview of research in that area.

Government and nonprofit organization participation is important in these cooperative efforts. The database on halon alternatives, for example, includes the results of Department of Defense and National Institute for Science and Technology findings, as well as academic, EPA, and industry findings.

For the automobile air conditioning recycling project, the EPA's Air and Energy Engineering Research Laboratory developed the analytical procedures, carried out the field work, and analyzed the results to enable recycling--all with industry oversight and contributions of expertise and resources. EPA provided an impartial public seal of approval on the results, but industry also viewed it as their project since they participated in and endorsed the study design, development of sampling methods and locations, testing procedures for the samples, the analysis of the results, and the conclusions.

Another advantage for industry of cooperative research rather than pursuing independent courses is that it will be better able to present Congress, EPA, and other regulatory agencies with a convincing record to make a decision on their technical promises. If the industry wants to argue that it needs more time to find alternatives, it will be in a better position if it can demonstrate that it is in fact following a reasonable plan for finding them. If it wants to argue that some uses are critical and alternatives cannot be easily found, that can also be argued more persuasively.

The bottom line of EPA's support of these groups is that they have a better chance of rapidly finding solutions and keeping U.S. industry competitive internationally than simple regulation alone could achieve. In putting together the work groups and consortia EPA ensures that the best talent available worldwide is brought to bear. EPA staff and technical experts are brought in to advise on problems as they arise and, as one problem or phase is completed, new expertise is brought in to help define and solve the next set of problems. Since some areas, such as refrigeration, are closely tied not only to stratospheric ozone depletion, but also to energy efficiency, it is likely that improvements in performance will be sought for many years to come and the results of the efforts will be beneficial in reducing both stratospheric ozone depletion and global warming.

Research In Progress

The EPA/ORD Air and Energy Engineering Research Laboratory (AEERL) is engaged in a number of projects to provide additional technical support to the effort for protection of stratospheric ozone. One of the first cooperative government/industry ventures was a joint project involving the Motor Vehicle Manufacturers Association of the United States (MVMA), the Mobile Air Conditioning Society, and the EPA. This project commenced in the early summer of 1988 and had as its goal the establishment of a level of purity for used automobile air conditioning refrigerant which would be acceptable to the automobile industry to encourage recovery and recycle of used refrigerant.

Such recovery and recycle can be important in reducing the nearly 18,000 metric tons of CFC-12 currently vented into the atmosphere each year when vehicle air conditioners are serviced. In January of this year, as a result of this joint study, car manufacturers agreed on a standard of purity for recycled CFC-12 which will allow automotive mechanics to reuse old refrigerant without voiding the warranty on the air conditioners. As a follow-on effort, Underwriters Laboratories is instituting a program to certify the capability of commercially available refrigerant recycle equipment for meeting the agreed upon purity standard. Manufacturers of recycle equipment will submit their equipment for certification voluntarily.

Another AEERL project is to describe alternatives to CFC usage in aerosol products with a major goal of encouraging other countries to move away from this CFC application. This is an area in which the U.S. can assume a leadership role since U.S. aerosol manufacturers have at least 10 years of experience using non-CFC propellants. However, even in the U.S. approximately 5,600 metric tons of the fully halogenated CFCs are still used in aerosol products that were exempted or not included in the general ban imposed in 1978.(7)

Examples of exempted aerosol products include: release agents for molds used to produce plastic and elastomeric materials; lubricants for rotary-type press-punches for pharmaceutical tablets; lubricants, cleaner-solvents, de-dusters, or coatings for industrial/institutional applications to electronic or electrical equipment; mercaptan stench warning devices for mine safety; and metered dose inhalant drugs. Nonregulated aerosol products

developed since the 1978 rule include products in which the CFC is the sole or active ingredient. Examples of these products include: drain openers, microscope slide cleaners, computer cleaners and de-dusters, boat horns, and portable polyurethane insulation foam generators.

Our studies have shown that, for non-medicinal products, any CFC-11 and CFC-12 present in the formulation can probably be replaced in the near-term with various combinations of HCFC-142b, HCFC-22, and CFC-113 to substantially reduce the total ozone depletion factor. Metered-dose oral and nasal inhalation pharmaceutical products currently represent about 15 percent of all CFC-based aerosols in the U.S. Reformulation to lower the ozone depletion factor for these products is somewhat more difficult owing in part to the strict need for a nonflammable, nontoxic propellant and in part to the current rather lengthy approval process for introducing a new formulation under the Food and Drug Administration's "New Drug Application" procedure. Over the longer term, reformulation to some of the new HCFCs and HFCs (e.g., HCFC-123 and HFC-134a) currently under development may be possible.

In many cases, regardless of the type of aerosol product, engineering questions remain to be answered. Some of these questions are: (1) Can the proposed products utilizing HCFCs be produced in existing manufacturing equipment? (2) Will the new formulations be considered satisfactory in performance while still limited to current Department of Transportation maximum pressures of 1342 kPa (54 °C)? and (3) What modifications in filling operations may be required? In countries which have not previously restricted the use of CFCs in aerosol products, substantial reductions may be possible by converting to hydrocarbon propellants such as has been accomplished in the U.S. However, there are major considerations involved including the availability of aerosol grade propane and butanes and the capital expense of installing equipment to handle the flammable propellants.

AEERL also has initiated a research program to determine the physical/chemical/thermal properties of possible new chemical alternatives to the Protocol compounds. This effort is spearheaded by two independent research teams--one at Clemson University headed by Professor Darryl DesMarteau, and one at The University of Tennessee headed by Professor James Adcock. This effort involves the property determinations (and synthesis, where needed) of selected partially fluorinated chemicals such as fluoroethers and partially hydrogenated three-carbon HCFCs. Insertion of bromine into the molecules will also be attempted in order to investigate the suitability of the new chemicals as candidates for halon replacements. In conjunction with project co-sponsors, the Electric Power Research Institute, and the principal investigators, approximately 15 chemicals including the principal products of direct fluorination of dimethylether have been selected for initial investigation.

As these chemicals are generated and purified, the following fundamental properties will be measured or derived:

- o normal boiling point
- o liquid density at two temperatures
- o critical temperature, pressure
- o liquid density versus temperature
- o vapor pressure versus temperature
- o ideal gas heat capacity versus temperature
- o vapor density
- o melting point
- o hydrolytic stability
- o vapor thermal conductivity.

Additional properties which are particularly relevant to fire suppression may be added to the list for the brominated derivatives. It is expected that property determinations for the bromine derivatives will be a useful contribution to a joint research consortium currently being formed by halon manufacturers, halon users, and various government agencies, including the EPA. The main objective of this program is to find replacement fire extinguishants for the fully halogenated halons as expeditiously as possible. As of this writing, a Technical Advisory Group has been formed to prepare the broad outlines of the goals of the program and how it will be implemented and administered.

AEERL is also sponsoring a project at the Massachusetts Institute of Technology in cooperation with the Department of Energy's Oak Ridge National Laboratory to better understand the mechanisms of heat transfer through plastic insulation foams and to investigate ways of maintaining or improving the thermal performance of these foams made without the benefit of CFCs. This is one of several projects suggested by private industry at an insulation foam workshop sponsored by DOE in June 1988. A follow-on workshop held in January of this year resulted in selection of a joint industry/DOE/EPA project to examine the long-term performance of polyisocyanurate roofing insulation panels made with HCFC-123 and HCFC-141b. This project will involve subjecting foam insulation panels to actual field conditions over a 2 to 3 year period and obtaining weekly averages of the thermal R-value along with a continuous time history of weather conditions. This effort to obtain realistic side-by-side product comparisons of the performance of the materials over time will be supplemented with laboratory tests on smaller specimens to develop laboratory protocols to predict long-term thermal performance.

In January of this year, a meeting was held in Washington, DC, to determine the level of commitment for a joint government/industry research effort to select a new refrigerant or refrigerant mixture for domestic refrigerators and freezers that would be less damaging to stratospheric ozone. Rationale for such a collaborative effort derived mainly from recent data showing that the use of HFC-134a, a candidate to replace CFC-12 in refrigerators, may result in a loss of energy efficiency of 5 to 15 percent. As increased energy usage generally translates into increased carbon dioxide emissions, it is important to find ways of simultaneously reducing CFC consumption and maintaining or improving energy efficiency. Furthermore, Third World countries are vitally interested in obtaining such refrigeration conveniences, but only at energy costs they can afford. AEERL, along with the

Department of Energy and the National Institute of Standards and Technology, is studying the possibility of using Non-Azeotropic Refrigerant Mixtures (NARMs) as possible replacements for CFC-12 in domestic refrigerator-freezers. The near-term goal is to demonstrate that more energy efficient appliances can be produced without the use of the fully halogenated CFC as the working fluid.

CFC-113 finds its greatest application as a solvent in the cleaning of electronic components such as in the defluxing of printed circuit boards. Given CFC-113's superior ability to remove the soldering fluxes currently required by military specifications, this solvent became a de facto specification itself. Beginning in the summer of 1988 a joint industry/military/EPA program began looking into possible alternatives to CFC-113 for electronic cleaning. This program will eventually involve round robin testing of alternative cleaning systems submitted by private industry in order to evaluate the ability of the alternatives to clean to the level of an agreed-upon standard. In addition to this program, several firms are independently exploring the possibility of converting to aqueous-based cleaning systems for various applications which now employ chlorinated solvent vapor degreasing and cold cleaning.

Under the terms of the Montreal Protocol manufactured goods containing the restricted compounds will not be allowed to be imported by parties to the Protocol from countries not party to the Protocol. AEERL has recently commenced a project designed to develop sampling and analytical protocols to detect the presence of Protocol compounds in finished products. Cellular plastic foams such as flexible polyurethane foam and rigid polyisocyanurate, polystyrene, polyethylene, and phenolic packaging and insulation foams are the first such products to be investigated.

Finally, the Protocol requires that parties allow consumption and production credits for destruction of the controlled substances. The EPA's Air and Energy Engineering Research Laboratory is currently reviewing available and anticipated technologies for the destruction of unwanted and waste CFCs and halons. This effort involves evaluating the overall comparative costs of destruction relative to recycling, describing the by-products generated by the destruction techniques, and the logistics associated with collecting the chemicals and monitoring their destruction.

While substantial progress has already been achieved in initiating programs designed to overcome technical and economic barriers to the phaseout of fully halogenated CFCs and halons, it is clear that these initiatives represent only the first steps. The first few months immediately preceding and following the entry into force of the Montreal Protocol have been well spent laying the groundwork for a host of collaborative government and industry research and development projects. Ahead lies the actual performance of the selected tasks. Successful fulfillment of the goal of finding alternatives for the Protocol compounds which are environmentally, economically, and technically acceptable will be facilitated by the continued cooperation of all affected industries and government as well as a willingness to share technical information.

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